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James W. McKinsey Jr.
Bridgewater State College

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Climate, Research and Agriculture

James W. McKinsey, Jr.



In the space of 176 years the Lower Mississippi has shortened itself 242 miles.

Therefore, any calm person who is not blind can see...that 742 years from now the Lower Mississippi will be only a mile and three-quarters long, and Cairo (Illinois) and New Orleans will have joined their streets together, and be plodding along comfortably under a single mayor and a mutual board of aldermen.

—Mark Twain
Life on the Mississippi, 1874

Prediction is very difficult, especially if it is about the future.

—Niels Bohr

In the late 1960s and early 1970s a number of groups popularized the notion of the “Limits to Growth.” Prominent among those groups were academics associated with Washington University in St. Louis and with MIT, and a broad collection of people who called themselves the “Club of Rome.” They based their arguments primarily on three factors: rapid population growth experienced in many countries during the 1950s and 1960s; stagnant food output, and consequent near-famine, in many areas of the world in the mid-60s; and an appeal to the finite, seemingly-fixed physical quantity of petroleum and other resources [and consequently diminishing returns to labor] with which to meet the looming Malthusian challenge. They often punctuated their arguments with expressions of dismay or outrage at the unsustainable global maldistribution of economic activity and reward: that one nation, home to three percent of the world’s population, consumed one-third of the world’s energy and disproportionately depleted various other resources. Their dire prediction was imminent economic collapse, to be followed by apocalyptic ecological, social and political disaster.

Some of their advocacy became more shrill with the OPEC oil embargo of the early 1970s, held up as both proof and foretaste of the disruption to come. Yet thirty years later these dire predictions have failed to materialize and it may be that the only clubs of Rome known to

this journal’s readership are AS Roma and SS Lazio of the Premier League. Niels Bohr was right: prediction is indeed very difficult.

Most economists were skeptical of the “Limits to Growth” hysteria, because it seemed to spring from an understanding of human behavior which was mechanistic, rigidly determined: if individuals or groups have been doing something, they will continue to do the same. The analysis seemed not to rise above simple extrapolation.

In contrast, the economic approach focuses on three things: the *environment* [both opportunities and constraints, some of which are made known through prices] in which people find themselves, their *goals*, and their *choices* and behavior in pursuit of those goals. A hallmark of that approach is the idea that when the environment changes, people adjust, make different choices, change their behavior in response. Although Mark Twain was not a trained economist, he understood the adjustment process well enough to parody those who would assert that trends go on indefinitely, that behavior continues unchanged.

Each of the three factors which underlay the “Limits to Growth” arguments turned out not to have continued as the Cassandras had expected. Population growth rates moderated: the demographic transition continued its course, and birth rates declined a few decades after death rates had fallen. Quantities of resources alleged to have been fixed, limited, turned out to be responsive to scarcity-induced higher prices, as economists expect [but the impetus towards moderation and conservation, suppressed perhaps in our age of SUVs, did receive reinforcement in those times—another effect of higher prices]. And perhaps most dramatic of all, food output was far from stagnant: increases in rice and wheat productivity and output were so great in the late 1960s and early 1970s that the phenomenon was perhaps infelicitously termed the “Green Revolution.”

The story of the “Green Revolution” is instructive to us on several levels: biological, organizational and economic. Biologically, the varieties (“landraces”) of food crops selected over many generations by farmers in South and Southeast Asia and large areas of Latin America, well-adapted to highly-specific local soil, climate, pest and disease, husbandry and other conditions, had mostly reached their maximum yield. Over the previous half

century or so farmer's adaptations, primarily in higher-income, usually temperate areas, had been greatly assisted by formal research programs at agricultural universities and state experiment stations. An early success was the development of hybrid corn; other early success came in sugar cane, bananas, and various food grains. Often the breeding goal was explicitly to increase yields. But just as frequently it was to confer host plant resistance to insects, diseases, or to various abiotic stresses including drought and heat.

Significantly less progress had occurred for food crop varieties grown in Asia; with little idle land available to bring under cultivation, it appeared that food output in those areas had neared its limits. What might seem an obvious solution was to add more inputs—especially fertilizer—to each hectare of land. However, few Asian landraces were very responsive to increased nutrient input, and those that were, especially in rice, tended to become top-heavy with the extra grain, and “lodge”: fall over and rot on the ground or in the flooded paddy. But agronomists had begun to assemble and catalog collections of germplasm, samples of as many varieties of each crop as they could find worldwide, with as many different traits and characteristics as nature provided. And advances in basic biology improved the ability of crop breeders to cross varieties in many ways, attempting to combine desirable traits.

Organizationally, much of the most important early work was focused in international centers supported by major foundations and the World Bank; the two most successful early locations were CYMMYT in Mexico, dealing with wheat and maize, and IRRI in the Philippines, dealing with rice. But the work required cooperation among scientists from several disciplines, and in many locations, from international centers to national and local agricultural experiment stations, in distinct agroclimatic regions within nations. Scientists at IRRI discovered that a gene from the Taiwanese rice variety Dee-Geo-Woo-Gen was both easy to transfer to the popular *indica* and *japonica* rice varieties, and would convey to those varieties a much shorter, stiffer stalk and a remarkable ability to grow satisfactorily in many low-input regimes while responding very well to fertilizer applications. Some called the new variety “miracle rice”; hyperbole, to be sure, but understandable, as IRRI's first released variety [IR-8] and its descendants spread throughout South and Southeast Asia, further adapted by crosses with indige-

nous varieties performed at local experiment stations, often increasing yields by more than one third over the traditional landrace varieties, averting the specter of famine.

Economically, this is a classic tale of adaptation in response to scarcity, scarcity made known partly through an increase in food prices, scarcity which was manifested partly in a humanitarian resolve by officers of foundations and international institutions. As often happens, because of this adaptation rice and wheat output increased substantially enough that they ultimately became relatively less expensive in many places, enabling both private and public expenditures later to be redirected elsewhere, thereby accelerating more general economic development. This story is also a classic tale of a mix between public and private activity, a strong example of public programs which benefit both producers and consumers. Importantly, the private activity consisted of individual farmers independently deciding to plant the new varieties on their land; nearly all of the research and breeding and varietal development was performed by public institutions, both

national and international, with almost no private firms involved in the research, breeding or seed dissemination. There were no plant patents at the time, and that absence of protection for the intellectual property represented by new plant varieties removed any incentives for private firms to engage in any related activity apart from hybrid crops [which did not produce germinable—growable—seed, thus requiring that farmers buy seeds from the inventing company every season].

The “Green Revolution” offered economists a major opportuni-

ty to participate and to study, as literally hundreds of economists played varied roles during and after the major crop breeding activities. One notable example is Robert Evenson, an economist now at Yale, who had worked at IRRI and the neighboring University of Los Baños in the early '70s. He has since informally led a loose confederation of agricultural economists around the world who have studied the economic impact of agronomic research in general, new crop varieties in particular. I have collaborated with him since the early 1980s in studying the varied but substantial impact of new crop varieties in India.

Three and four decades later, all echoes of the “Limits to Growth” seem to have faded to silence. But taking its place is widespread if diffuse concern with climate



change, fostering the fear that once again global natural forces may disrupt the planet's economies in general, and food supplies in particular.

Although most U.S. energy companies deny that anything is happening, and the rest of the Executive branch tries to squelch EPA findings, there is very strong consensus within the serious scientific community that human activity has increased the atmospheric concentration of carbon dioxide and other so-called greenhouse gases over the past century or so to the point where the earth's climate is being affected. The impact is seen in very slowly rising mean temperatures, more volatile temperature and rainfall patterns including an evident increase in the frequency and severity of storms, and apparently some change in weather patterns such as the jet stream. Just as was true before, this increased concern sometimes spawns hysteria, as perhaps reflected in the recent movie *The Day After Tomorrow*; it sometimes also tempts people again into prediction by mere extrapolation, counting the years until coastal cities are inundated by rising sea levels as the polar ice caps melt, or counting the years until the Sahara desert, continuing to expand at recent rates, grows like Twain's Mississippi to extend from the headwaters of the Nile to the Mediterranean.

But beyond the hysteria is more restrained, more nuanced, more plausible concern. Because climate—temperature, rainfall amounts and patterns, sunlight—is fundamental to crop growth, and because therefore crops which are suited, successfully adapted, to one prevailing agroclimatic regime often perform very poorly in even slightly different regimes, it is reasonable to wonder whether global climate change would reduce food output. Numerous laboratory and greenhouse studies, supported by some mathematical models, suggest that it would, although for many reasons these studies cannot be conclusive.

Recent field evidence of the effect of climate change on agriculture comes in intriguing forms. In August botanists revealed that magnolia and dogwood trees in Boston's Arnold Arboretum were blooming five to eight days earlier than a century ago; they attributed the change to warmer spring temperatures. Ironically, at the birthplace of the "Green Revolution," botanists at IRRI recently announced a slight decrease in the yields of specific rice varieties continually grown in their experimental plots over the past decade or two. While admitting that they were not sure of the precise biological mechanism responsible for the decreased yield, they attributed it to a small observed increase in minimum *night-time* temperatures during the early growth phases in the spring.

Economists who study climate change and its implications understand adjustment just as well as did Twain, and understand the role of agricultural research and the development of new crop varieties in that adjustment

just as well as did the economists who studied the "Green Revolution." Of course, many of the economists are the same: Evenson and I have continued to study the economic impact of research, and new crop varieties, in India in the context of climate change. We have found what we believe is compelling statistical evidence that well-organized, locally-adapted breeding programs can, and probably have begun to, mitigate harmful effects of higher temperatures and other manifestations of anthropogenic climate change.

Logic and history reinforce our evidence. The fact that varieties of rice which were selected for their optimal performance in one climate regime suffer a lower yield in another regime does not mean that average cultivated rice yields must decline as climate changes. It simply means that there is scope for continued breeding activity, continuing and more closely focusing on the decades-old experiences accumulated crossing strains of the crop which are tolerant of higher temperature with varieties exhibiting other desirable characteristics, selecting the best and releasing them for further local adaptation.

Scientists have had dramatic success with similar efforts, adapting soy beans, a very high-value crop previously suited only for warm regions such as the lower Midwest in the United States or portions of northern Brazil, making it tolerant of cooler weather and thus enabling its profuse and highly profitable growth in northern Iowa, Minnesota, and southern Brazil. The scientific challenge to breed heat tolerance into a plant is biologically no different from, nor more difficult than, the successfully-mastered challenge to breed cold tolerance into soy beans. The international collections of germplasm contain strains of rice grown in such a variety of agroclimatic regimes that many possible crosses exist. And the appearance in the 1990s in nearly every nation of plant patents has created an incentive for private seed-producing firms to devote their considerable scientific and financial resources to the task alongside the now-mature international and national research centers.

Climate is changing; farmers will adapt. National and international research systems, in some cases working alongside or competing with private seed companies, will facilitate that adaptation. With deference to Bohr, we cannot predict the exact outcome of the research and the adaptation which it fosters, but we can be confident that mere extrapolations of harm will prove incorrect.

—James W. McKinsey, Jr. is Assistant Professor of Economics